COMPARISON FINE SPRAY NOZZLE FOR TWO PHASE FLOW WITHIN EXPERIMENTAL AND SIMULATION

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ABSTRACT

The conversion of bulk liquid into fine spray is very important nowadays in several industrial process and has many application in agriculture, meteorology, and medicine. So, the design to develop a fine spray nozzle was varies according to the application. However, new development in fine spray nozzle have been achieved and implement better than fine spray nozzle from Halton Group Asia Sdn. Bhd. Currently, the nozzle from Halton Group used are produce in bulk liquid condition. The improvement that make are the nozzle use low pressure with very fine water spray. This research was focused on comparison for fine spray nozzle between simulation and experimental. The observation focused on flow characteristic that produce by mist spray. Multiphase nozzle were used with air and water as a medium . Six pressure inlet different are used during the experiment. They are 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 bar. They are three type of nozzles been tested Nozzle A, Nozzle B and Nozzle C. Nozzle A have eight air inlet slot which give a better performance compared to other nozzles. The result evaluated from this experiment are spray angle and the penetration. Nozzle A was sprayed with 3.0 bar of water and air pressure. Mass flowrate for this pressure are 5.67×10^{-3} kgs^{-1} for water and 2.698×10^{-4} kgs^{-1} for air. The angle of spray between experimental and simulation are 35.54° and 33.5° respectively. As a result, the percentage of similarity are 94.26%. High speed camera are used to visualize the result an the software were used to simulate the fine spray ANSYS FLUENT version 14.5. By using fine spray technology, it can trap dust and small particle in air inside kitchen hood more effective and can consume less water.

ABSTRAK

Pada masa sekarang, proses penukaran cecair kepada semburan halus amat penting di dalam beberapa proses industri dan aplikasinya banyak di dalam aplikasi pertanian, meteorologi dan perubatan. Maka, reka bentuk *nozzle* semburan halus berbeza mengikut aplikasinya. Walau bagaimanapun, sebuah *nozzle* semburan halus telah dibina semula bagi menambah baik *nozzle* milik Halton Group Asia Sdn Bhd. *Nozzle* milik Halton hanya menghasilkan semburan kasar. Penambah baikkan yang dibuat adalah *nozzle* tersebut menggunakan tekanan udara yang rendah untuk menghasilkan semburan halus. Fokus untuk kajian ini adalah bagi membandingkan *nozzle* semburan halus di antara eksperimen dan simulasi. *Nozzle* ini merupakan jenis *multiphase* di mana air dan udara digunakan. Enam jenis tekanan telah digunakan di dalam eksperimen ini. Ia adalah 0.5, 1.0, 1.5, 2.0, 2.5 dan 3.0 bar. Terdapat tiga jenis *nozzle* telah dikaji iaitu Nozzle A, Nozzle B, dan Nozzle C dan Nozzle A yang mempunyai lapan slot masukkan udara memberi prestasi yang lebih baik dari *nozzle* yang lain. Keputusan yang telah diambil adalah sudut semburan dan penembusan. Nozzle A telah menggunakan tekanan udara dan air sebanyak 3.0 bar. Kadar alir jisim air yang dihasilkan adalah $5.67x10^{-3}kgs^{-1}$ dan bagi udara pula adalah $2.698x10^{-4}kgs^{-1}$. Sudut semburan di antara eksperimen dan simulasi adalah 35.54° dan 33.5°. Hasilnya, peratusan persamaan adalah sebanyak 94.26%. Kamera halaju tinggi telah diguna untuk mendapatkan imej semburan dan perisian yang digunakan untuk simulasi adalah ANSYS FLUENT versi 14.5. Penggunaan teknologi semburan halus ini dapat memerangkap habuk dan partikel halus udara di dalam hud dapur dengan lebih berkesan dan penggunaan air untuk bekalan *nozzle* semburan halus juga dapat dijimatkan.

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INTRODUCTION

1.1 Background of study

The transformation of bulk liquid into sprays and other physical dispersions of small particles in a gaseous atmosphere is importance in several industrial processes and has many other application in agriculture, meteorology, and medicine. Numerous spray devices have been developed, and they are generally designated as atomizers or nozzles. Many experimental and theoretical studies about the atomization method have been carried out since the atomizer was used in the diesel engine in 1892 [1].

The importance of drop size for many combustion and industrial processes that utilize liquid sprays is attested to by the proliferation of techniques available for drop size measurement. No single technique is completely satisfactory but each technique has its own advantages and drawbacks, depending on the application. Direct methods include those in which individual drops are collected on slide for subsequent measurement and counting or in which droplets are frozen and sized as solid particles. With the impaction methods the drop are sorted on the basis of inertial differences. Depending on its size, a droplet may impact or fail to impact on a solid surface or may follow a different trajectory. This allows all the drops in a spray to be sorted into different size and categories.

The conversion of bulk liquid into fine spray is very important nowadays in several industrial process and has many application in agriculture, meteorology, and medicine. So, the design to develop a fine spray nozzle was varies according to the application. However, new development in fine spray nozzle have been achieved and implement better than fine spray nozzle from Halton Group Asia Sdn. Bhd. Currently, the nozzle from Halton Group used are produce in bulk liquid condition. The improvement that make are the nozzle use low pressure with very fine water spray. This research was focused on comparison for fine spray nozzle between simulation and experimental.

1.2 Problem Statement

Currently, majority of the users using the spray nozzle that already sold in the market. The spray nozzle that sold in the market has a weakness such as need high pressure and more water consumption. Using high pressure mean consume more energy usage, using more volume of water mean the droplet size of water still large and the nozzle need modification.

Thus we need is to produce a better type of nozzle. We need to produce the nozzle that use low pressure with very fine water spray. Nowadays, the industrial produce many types of spray nozzle for example air assist, air blast, rotary and pressure atomizer. This types of nozzle have different shapes and various form of pressure atomizer but still using a high pressure and a larger droplet size. Further research must be done in this field to improve the spray nozzle.

1.3 Objectives

1. To observe flow characteristic that produce by mist spray.
2. Analysis flow visualization inside the nozzle.
3. Validation on mist spray between the experiment and simulation.

1.4 Scope of Study

1. Experiment have been conducted with water and air pressure 0.5, 1.0, 1.5, 2.0, 2.5, dan 3.0 bar .
2. Water were used as liquid agent.

3. Simulation analysis using ANSYS software.
4. Material for the nozzle is stainless steel.
5. Three different nozzle will be tested which have 4, 8 and 6 air flow holes.
6. The fine spray nozzle was followed the act of treatment of aerosol Section 2.2.4 and 2.2.6 of SGN 5.06

1.5 Significant of Study

1. Many new technologies that relate with fine spray will be developed.
2. Low pressure to produce fine spray will consume less energy require by the system thus it reduce the cost [3].

CHAPTER 2

LITERATURE REVIEW

2.1 Atomization

Atomization is the process of generating drops and it begins when liquid was forcing through a nozzle. The causes of the liquid to emerge as small ligaments when the potential energy of the liquid (measured as liquid pressure for hydraulic nozzles or liquid and air pressure for two-fluid nozzles) along with the geometry. Drops, droplets or liquid particles as shown in Figure 2.1 happens when these ligaments then break up further into very small pieces.

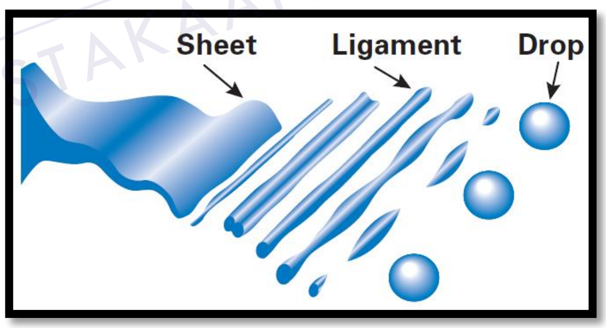

Figure 2.1 : Atomization [1]

This range is referred to as a drop size distribution when each spray provides a range of drop sizes. The breakup of a liquid as it emerges from an orifice is a simple explanation of this process. Various spray nozzles produce various spray patterns such as hollow cone, full cone, flat spray and others when it have different shaped orifices. It will vary significantly from one type to another and the drop size distribution will be dependent on the nozzle type. The drop size also was affected to the factors such as the liquid properties, nozzle capacity, spraying pressure and spray angle.

During the last decade, the importance of drop size information has increased considerably. Information for effective use was important to the many spray applications such as evaporative cooling, gas conditioning, fire suppression, spray drying and agricultural spraying [1].

2.1.1 Droplet Size Classification

The size of the spray droplets created during an application plays a crucial role efficacy of the application. Diameter is the measurement for spray droplets and micron (1 micron equal to 0.0001cm) was used for the unit of measurement. Smallest to the largest is a range of droplet sizes. It is referred to as the categories of droplet size when the nozzle produce this range of droplet sizes. The best method for achieving a specific droplet size with application are to categories the droplet size [6].

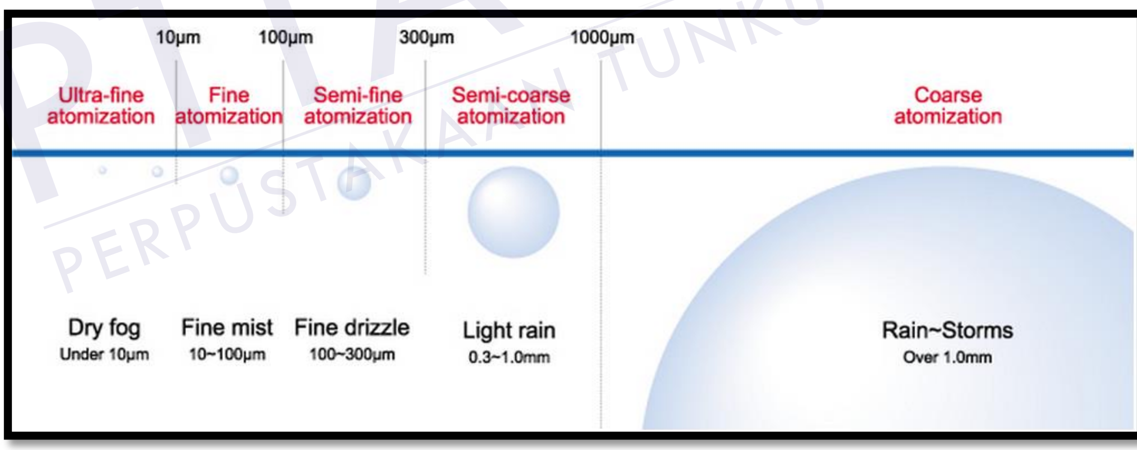

Figure 2.2: Categories of spray droplet size in micron [5]

2.1.2 Factors of Droplet Size

According to the following factors, the size of droplets sprayed from a spray nozzle was varies [9].

1. **Types of nozzles**: Full cone type nozzles produce smaller droplets than flat spray types even the pressure and flowrate inlet are the same. The former that produced the diameter of droplets can sometimes be several times smaller than those produced by the latter.
2. **Pressure**: The smaller droplets was appeared when pressure increase at inlet. For example, a spray nozzle that produces droplets of 1,000 microns at 1Mpa will produce much smaller droplets (of several tens of microns) if pressure is increased to 10MPa.
3. **Flow rate:** The smaller droplets was appeared when the value flow rate are reduced. For example, a spray nozzle that delivers very small volume of liquid, such as 10ml/min, produces droplets of several tens of microns. A spray nozzle that delivers high volumes of liquid, such as 1,000 l/min, produces (at the same pressure) droplets of several thousands of microns. When flow rate is increased or decreased droplet diameter can, therefore, be several hundred times greater or smaller.
4. **Fluid:** Two mixed fluids (including gas) sprayed by a nozzle can produce far finer droplets than a nozzle that sprays only liquid. Furthermore, droplet size can be reduced if the gas flow rate of the former spray nozzle is increased. Normal nozzles that spray two mixed fluids normally produced the mean droplet diameter several tens of microns.

2.1.3 Small Droplets Increase Drift.

The potential for evaporation, drift, canopy penetration, and deposition of the spray particles need to be considered even atomizing is the spray solution into very small droplets that increased the coverage possible. Drift is the greater risk to the smaller droplet. As shown in Table 2.1, 1 inch in less than one second was traveled by a 20 micron droplet before the water droplet evaporates.

It reach a horizontal trajectory in a very short time and evaporate rapidly when droplets less than 100 microns in size. Rather than reaching the target, the pesticide contained in these water droplets become very small aerosols, which remain in the air until picked up in falling rain. Because of their large surface area, droplets over 150 microns in size resist evaporation much more than smaller droplets. Therefore, when the diameter of droplets is increased to about 150 microns, the potential for drift rapidly decreases [10].

Table 2.1: Spray droplets and distance traveled [10].

Spray droplets: evaporation and distance traveled*

Droplet diameter (microns)	**Terminal velocity** (feet per second)	**Drop diameter after water evaporates** (microns)	**Time to evaporate** (seconds)	**Distance traveled from nozzle** (inches)
20	0.04	7	0.30	Less than 1
50	0.25	17	1.80	3
100	0.91	33	7.00	9
150	1.70	50	16.0	16
200	2.40	67	29.0	25

***Conditions assumed:** • Temperature: 90 °F • Relative humidity: 36%
• Spray pressure: 25 pounds per square inch
• Pesticide solution: 3.75%

2.1.4 How to Reduce Drift

1. **Select a nozzle that produces coarse droplets:** To provide necessary coverage, use droplets that are as coarse as practical.
2. **Use the lower end of the pressure range:** Many more small droplets (less than 100 microns) was generated by a high pressure generate. Do not exceed 40 to 45 psi under most conditions.
3. **Lower boom height:** Height was increases with wind speed. Off-target drift is reduced if boom height is a few inches lower.

4. **Increase nozzle size:** Drift was reduced by a larger capacity of nozzles. Increase to nozzles that put out 15 to 20 GPA if the nozzles that output 10 to 15 gallons per acre (GPA).
5. **Spray when wind speeds are less than 10 m.p.h.:** The increases of wind will make a spray move off-target.
6. **Spray when wind is moving away from sensitive crops:** If sensitive plants are downwind, leave a buffer zone. When the wind changes direction, spray the buffer zone.
7. **Do not spray when the air is very calm:** Spray can move slowly downwind during calm air, or an inversion and reduces air mixing. Early morning or near bodies of water generally inversions generally occur.
8. **Use a drift control additive when needed:** Average droplet size produced by nozzles increased when using the drift control additives.

2.2 Nozzle

A device which makes use of the pressure energy of a liquid to increase its speed through an orifice and break it into drops called as a nozzle. Most important physical aspects firstly an overview of the of the internal flow through a nozzle will be given. The definition of at least two phases are requirement for the multiphase simulation of nozzle flow which is liquid and vapourization, and eventually air for the boundary conditions in the atmosphere [4].

2.2.1 Flow Principle

Tight control of drop size and spray coverage was controlled by a high efficiency nozzles. To achieve this very small drop size, a multi-stage atomization process must be used as shown in Figure 2.3 [3].

1. **Stage one : Primary Fluid Breakup**

Behind the air guide, air and liquid combine. Primary atomization of the liquid stream will be provide when the pressure drop across the air guide orifice.

2. **Stage two : Secondary Fluid Breakup**

Additional mechanical breakup happen when focused stream impacts the target bolt.

3. **Stage three : Final Mixing**

Air cap acts as a final mixing chamber. An additional, pressure drop provides the final atomization after a liquid crosses multiple orifices.

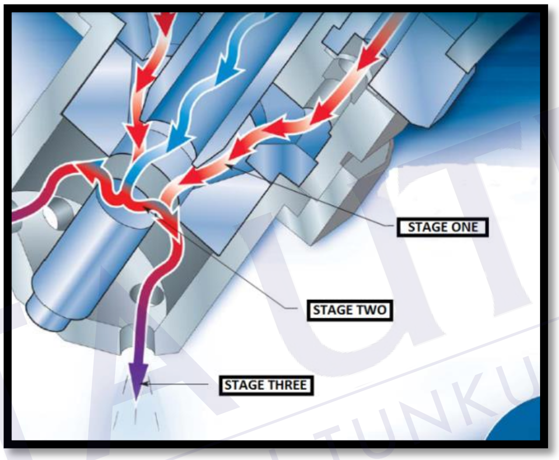

Figure 2.3: Flow principle for nozzle [3]

2.2.2 Techniques for Spray Production

To produce a spray, many different techniques can be used. The following nozzle types can be used in industrial applications to generate a liquid spray based on the different techniques [8].

1. **Pressure nozzles:** This nozzle is the simplest type, where the liquid to be sprayed is fed under pressure, an orifice is opened into a chamber. Spray pattern, flow rate and spray angle produced through the orifice by a spray with depending upon the orifice edge profile and the design of the inside pressure chamber.
2. **Turbulence nozzles:** The liquid moving towards the chamber preceding the orifice is given a rotational speed component in these nozzles, so as to open up in

a conical shape as soon as it leaves the orifice edge because of centrifugal force. The drops produced can be confined to the cone outer surface (hollow cone spray) or be evenly distributed to fill the entire volume of the cone (full cone spray based on the nozzle design and the technique used to generate the rotational speed.

3. **Impact nozzle:** An impact of the liquid jet onto a properly designed surface will produced if the desired spray shape is obtained. After leaving the nozzle edge, the liquid jet is subsequently changed into a fluid lamina and then broken into drops with the desired spray pattern.
4. **Air assisted atomizers:** By means of air assisted atomizers, working upon various different principles, fine and very fine sprays can be obtained.

2.2.3 Spray Pattern

The shape of their spray pattern is the most basic distinguishing characteristic and there are many types of spray nozzles**.** Determining the type of spray pattern required for a particular operation is the typically beginning of nozzle selections [9]**.**

2.2.3.1 Full Cone Pattern

The droplets are distributed into a volume which is limited by a cone in a full cone spray, having its origin point at the nozzle orifice. In a large variety of industrial processes this such spray pattern is commonly used, since it is the one which allows to distribute in an even way the water flow onto a surface. To evenly spray cooling liquid on a still surface, the full cone spray pattern is therefore useful, as a typical example. Distribute liquid droplets within a certain volume is an another typical use, like for example evenly distributing water droplets in the inside volume of a cooling tower because of the wide number of processes performed by means of full cone nozzles. Where the full cone spray pattern, or a pattern similar to a full cone one, is obtained by different techniques, the original shape has evolved into a range of specialized types.

1. **Standard full cone (turbulence nozzle)**

   Shaped vane placed at the nozzle inlet usually used by the nozzle as shown in Figure 2.4, to give a rotational speed to the fluid flowing through the nozzle because of the rotational speed of the fluid, water exiting the nozzle orifice is subjected to centrifugal force and opens up in the shape of a full cone. The extent of the angle of the cone is a function of both exit speed (created from the inlet pressure) and the internal design of the nozzle. It can vary in practice from 15° to 120°. These nozzles can be also produced as square full cone nozzles, where the square shape of the pyramidal spray is obtained by a special design of the outlet orifice. Two important details have to be noted from the system designer when using these type of nozzles is:

a) The spray angle is measured on the side of the square section
b) The square section of the spray rotates within the distance from the nozzle orifice to the target area.

Figure 2.4: Standard full cone (turbulence nozzle) [9]

2. **Spiral full cone (deflection nozzle)**

   The nozzle as shown in Figure 2.5 is not properly a full cone, but rather a continuous liquid curtain evolving with the shape of a spiral inside a conical volume. The disadvantage of a scarcely even distribution is compensated by an exceptionally good resistance to plugging, which makes this nozzle the best choice in those applications where safety or system reliability are the prime concern. For example is firefighting systems.

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